# LONGITUDINAL FITNESS TESTING – SUPERVISION OF TRAINING IN YOUNG ALPINE SKI RACERS

**Christian Raschner, Carson Patterson, Hans-Peter Platzer**

**Institute of Sport Science, University of Innsbruck, Austria**

Alpine ski racing demands a multitude of technical skills and excellent physical abilities. Longitudinal systematic fitness testing and supervision of training in young alpine ski racers is one key factor in the success of the Austrian ski teams. The established norm profiles for sport motor function and fitness tests in all age groups of ski racers can help in detecting fitness deficits early. Testing over the last 10 years has shown that Austrian young ski racers (e.g. boys) have an excellent conditioning level compared to other youth athletes from different sport disciplines. Testing of training efficiency demands that the coaches continually critique and revise their programs. Coordinated off/on snow courses and optimal intergroup communications under the supervision of the Austrian Ski Federation are important frameworks for a scientific based longitudinal training process.

**KEY WORDS:** longitudinal, fitness testing, evidence based training, alpine skiing.

**INTRODUCTION:** Alpine ski racing demands a multitude of technical skills and excellent physical abilities, but there is relatively little current published sport scientific data regarding conditioning characteristics of a successful alpine ski racer.
Neumayr et al. (2003), using data from Austrian world cup athletes during the period of 1997 to 2000 concluded that aerobic capacity is paramount. Bosco (1997) maintained after testing Italian ski racers that anaerobic endurance was most important in determining performance potential, and advised against high volume aerobic training. Older literature (Brown & Wilkinson 1983, White & Johnson 1991) indicated aerobic as well as anaerobic power as important factors for athletes in skiing racing.
It is generally accepted by experts that alpine ski racers must possess very high leg strength and power. Several EMG measurements demonstrated the importance of eccentric muscle action during racing situations (Hintermeister et al. 1997, Berg et al. 1995). Frick et al. (1997) analysed slalom turns and assumed that muscle actions use a slow type of SSC. In recent years Austrians strength training programs also focuses on increasing maximal core strength and coordination/proprioception in all age groups.
It has already been stated (White and Johnson, 1993) that no specific physiological parameter can predict results in high level alpine ski racers. Due to the constant evolution of ski equipment as well as changing environmental factors (e.g. artificial snow) and the complexity of skiing techniques, there is still no one single physiological variable that can determine success.
The complexity of ski racing demands that fitness testing of ski racers is multi-faceted. Longitudinal systematic fitness testing and supervision of training in young alpine ski racers is one key factor in the success of the Austrian ski teams.

**METHOD:** Training quality is optimized through systematic planning and goal oriented training programs, especially in a seasonal sport like alpine ski racing. Testing at all age groups must aid in this process, examining the sport specific parameters so that test results can determine current individual status and evaluate individual progress. Even young ski racers must develop appropriate physical fitness and skills (e.g. mastering power cleans and squats) in order to cope with the demands that are placed upon the musculoskeletal system. Injury prevention is a critical factor in every training program. Experts agree that a good fitness aids in the prevention of knee injuries, especially ACL tears, which are unfortunately still the most common knee injuries in alpine skiing.
In Austria the provincial ski federations as well as schools which focus on ski sport – 7 secondary schools (e.g. SHS Neustift, SHS Schruns) and several high schools like Stams or Schladming are an essential part of this concept. Coordinated off/on snow courses and

optimal intergroup communications under the supervision of the Austrian Ski Federation are important frameworks for a scientific based longitudinal training process of the up and coming ski racers. It should be noted that the 10 - 16 years age group can be very sensitive to training volume and intensity due to physical development changes which are occurring. Therefore it is imperative that test batteries as well as training exercises and programs are designed with the physical development and sensitivity of the athletes in mind.
A fitness testing concept starting from age 10 up to the national teams is in use. In the last 10 years nearly all of the young ski racers from 12 to 18 years undergo a permanent physiological testing battery two or three times annually. The physical preparation program of the Austrian Ski Federation ski racers has included a more comprehensive test battery for some years now.
For the younger athletes (10 to 12years) specially designed simple tests are administered by the ski clubs themselves.
Most of the testing devises for the 12-18 year old athletes are self developed (e.g. isometric leg and trunk tester, jump coordination test) and fulfil the scientific criteria for high quality testing. The modular construction system ITEM (see Fig. 1) was chosen to construct and build most of these devices. In sum there are nine respectively eight tests administered.

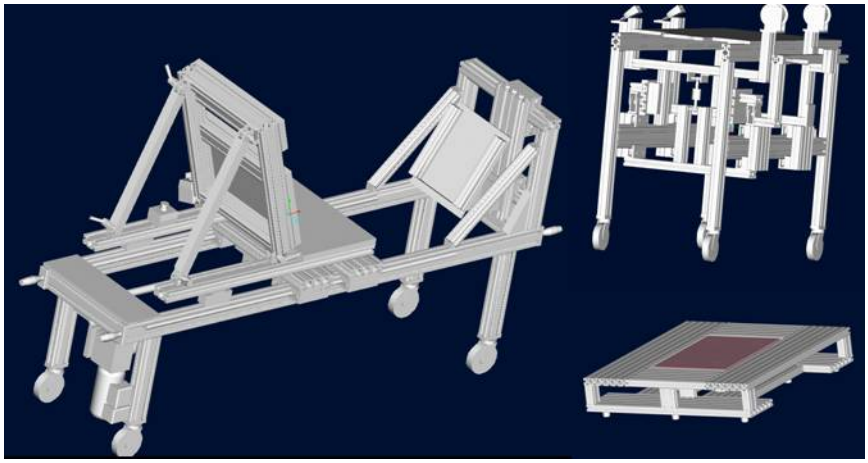

Figure 1: Test devices - isometric leg/trunk tester and Kistler force plate platform

The tests are: a maximal isometric unilateral leg extension strength test, a maximal isometric core strength test, jump tests on a Kistler force platform (counter movement jump, special power test and reactive strength test), a jump coordination test, a strength endurance test, and two endurance tests – an anaerobic line-run and the Cooper test (Raschner et al. 2005).

**RESULTS:** For example more than 330 young ski racers from the ski gymnasium Stams have been tested over 10 years. The best value of each test in each age group was used for calculation. The established longitudinal mean data (see table 1) and norm profiles (figure 2) from fitness tests in the 14 to 19 years age groups of young ski racers can help in detecting deficits early and correcting the problem(s).

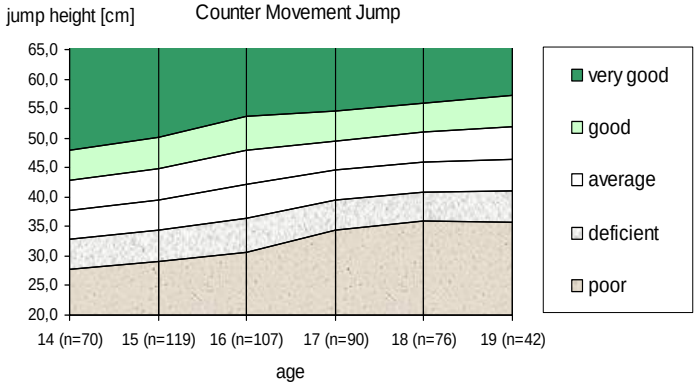


Figure 2: Norm data for CMJ (male)

**DISCUSSION:** Obviously skiing is the most important part of training but due to financial and organizational reasons off season training is dominated in youth by dry land training. Testing over the last 10 years has shown that Austrian young ski racers (e.g. boys) have an excellent conditioning level compared to other youth athletes from different sport disciplines.

Table 1 Body composition and motor skills - Mean & SD - of 14-19 year old ski racers (male)

| Test | Age | N | Mean | SD | Test | Age | N | Mean | SD | Test | Age | N | Mean | SD |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Height [cm] | 14 | 69 | 168,2 | 7,0 | Abs. strength right [N] | 14 | 69 | 1 347 | 243,0 | Rel. abdom. strength [N/kg] | 14 | 70 | 15,05 | 2,92 |
| | 15 | 123 | 172,5 | 6,2 | | 15 | 121 | 1 522 | 251,8 | | 15 | 123 | 15,17 | 2,94 |
| | 16 | 110 | 175,3 | 5,9 | | 16 | 108 | 1 708 | 264,4 | | 16 | 109 | 15,92 | 2,66 |
| | 17 | 95 | 177,5 | 5,7 | | 17 | 92 | 1 901 | 275,3 | | 17 | 93 | 16,63 | 2,95 |
| | 18 | 75 | 178,1 | 5,5 | | 18 | 79 | 1 998 | 252,6 | | 18 | 78 | 16,80 | 3,07 |
| | 19 | 41 | 178,6 | 4,6 | | 19 | 43 | 2 058 | 248,3 | | 19 | 42 | 17,26 | 3,22 |
| Weight [kg] | 14 | 70 | 57,5 | 7,7 | Abs. strength left [N] | 14 | 70 | 1 305 | 231,3 | Rel. erectors strength [N/kg] | 14 | 70 | 15,54 | 3,94 |
| | 15 | 123 | 63,5 | 7,3 | | 15 | 121 | 1 481 | 245,2 | | 15 | 123 | 16,37 | 4,13 |
| | 16 | 110 | 68,4 | 7,4 | | 16 | 109 | 1 642 | 258,9 | | 16 | 109 | 17,34 | 3,63 |
| | 17 | 94 | 72,3 | 7,2 | | 17 | 93 | 1 834 | 279,3 | | 17 | 92 | 18,27 | 3,61 |
| | 18 | 79 | 74,7 | 7,3 | | 18 | 78 | 1 935 | 273,7 | | 18 | 77 | 18,33 | 4,56 |
| | 19 | 42 | 76,6 | 5,7 | | 19 | 42 | 1 986 | 269,7 | | 19 | 42 | 19,49 | 4,09 |
| Cooper-test [m] | 14 | 68 | 2 989 | 171 | Rel. strength right [N/kg] | 14 | 69 | 23,64 | 2,593 | Core torque abdom. [Nm] | 14 | 70 | 400 | 110,8 |
| | 15 | 109 | 3 065 | 166 | | 15 | 121 | 24,19 | 2,972 | | 15 | 123 | 464 | 114,9 |
| | 16 | 102 | 3 118 | 144 | | 16 | 108 | 25,25 | 3,190 | | 16 | 110 | 534 | 105,3 |
| | 17 | 83 | 3 111 | 122 | | 17 | 92 | 26,64 | 3,415 | | 17 | 94 | 605 | 138,3 |
| | 18 | 63 | 3 081 | 139 | | 18 | 78 | 27,19 | 3,107 | | 18 | 78 | 641 | 128,9 |
| | 19 | 28 | 3 090 | 114 | | 19 | 43 | 27,18 | 3,400 | | 19 | 42 | 673 | 127,6 |
| An-aerobic linerun [s] | 14 | 70 | 72,5 | 3,84 | Rel. strength left [N/kg] | 14 | 70 | 22,84 | 2,632 | Core torque erectors [Nm] | 14 | 70 | 454 | 167,7 |
| | 15 | 119 | 70,4 | 3,44 | | 15 | 121 | 23,56 | 2,798 | | 15 | 123 | 583 | 340,6 |
| | 16 | 104 | 67,7 | 2,99 | | 16 | 109 | 24,28 | 3,049 | | 16 | 110 | 644 | 173,9 |
| | 17 | 90 | 66,5 | 3,39 | | 17 | 93 | 25,66 | 3,371 | | 17 | 93 | 725 | 199,0 |
| | 18 | 64 | 65,8 | 3,27 | | 18 | 78 | 26,18 | 3,422 | | 18 | 77 | 765 | 226,6 |
| | 19 | 31 | 65,3 | 2,98 | | 19 | 42 | 26,30 | 3,638 | | 19 | 42 | 830 | 198,1 |
| Jump-coordi-nation-test [s] | 14 | 70 | 10,06 | 0,61 | Abs. abdom. strength [N] | 14 | 70 | 852 | 206,2 | Ski-specific CMJ [cm] | 14 | 70 | 31,6 | 4,99 |
| | 15 | 119 | 9,92 | 0,58 | | 15 | 123 | 946 | 220,9 | | 15 | 119 | 33,9 | 5,04 |
| | 16 | 101 | 9,61 | 0,55 | | 16 | 110 | 1 076 | 204,5 | | 16 | 107 | 36,0 | 5,09 |
| | 17 | 89 | 9,40 | 0,48 | | 17 | 94 | 1 187 | 252,4 | | 17 | 90 | 37,7 | 4,45 |
| | 18 | 63 | 9,24 | 0,51 | | 18 | 78 | 1 239 | 235,8 | | 18 | 76 | 39,2 | 4,54 |
| | 19 | 36 | 9,19 | 0,44 | | 19 | 42 | 1 304 | 243,1 | | 19 | 42 | 39,4 | 4,85 |
| Strength en-durance test [#] | 14 | 70 | 97,4 | 6,65 | Abs. erectors strength [N] | 14 | 70 | 890 | 281,6 | Re-active strength index | 14 | 70 | 1,65 | 0,36 |
| | 15 | 116 | 99,3 | 7,68 | | 15 | 123 | 1 032 | 313,4 | | 15 | 120 | 1,71 | 0,36 |
| | 16 | 100 | 104,2 | 6,53 | | 16 | 110 | 1 180 | 288,2 | | 16 | 107 | 1,84 | 0,31 |
| | 17 | 89 | 105,0 | 6,57 | | 17 | 93 | 1 306 | 314,2 | | 17 | 90 | 1,94 | 0,35 |
| | 18 | 60 | 107,2 | 6,15 | | 18 | 77 | 1 359 | 373,3 | | 18 | 71 | 2,03 | 0,34 |
| | 19 | 32 | 107,2 | 5,75 | | 19 | 42 | 1 482 | 341,8 | | 19 | 40 | 2,05 | 0,39 |

Kollath et al. (2006) analysed young soccer players in sprint and power tests and also gave test result information from other sports (e.g. tennis, volleyball). Comparing the different male age groups one can see that the ski racers power is higher than average. Surprisingly, the jumping heights from the 14 to 19 year old ski racers were in all age groups higher than Greece basketball players (Kellis et al., 1999). Contrary to the study from Gröger et al. (2001) with ice hockey players where the unilateral relative isometric leg extension strength increased from 15 to 16 and then decreased slightly from the age of 17 on, Austrians top junior skiers increased their strength continuously from 14 to 19.
Because of a heavy competition schedule and training/racing at altitudes between 2000 and 3000m, excellent aerobic/anaerobic capacity is necessary, and as seen in table 1, this is accomplished.

**CONCLUSION:** All young athletes must have a solid fitness base to withstand the rigors of a ski season, so aerobic fitness is critical and a certain level must be achieved. Coordination training often combined with strength training is a very important aspect of conditioning in youth. A DVD produced by the Austrian Ski Federation and the Austrian Soccer Federation provides examples of coordination and strength exercises for youth. It combines training software with age-appropriate exercises and is available to all ski coaches in Austria. Great emphasis was put on core training because core stability in ski racing is of utmost

importance. Kibler et al. (2006) stated that core function for body stabilisation and also force generation is a pivotal component in athletics activities. Decreased core stability has been suggested to contribute to lower extremity injuries (e.g. ACL ruptures in ski racing) (Leeturn et al., 2004). In recent years balance, rhythm, kinesthetic sense and other coordination abilities vital to ski racing are emphasized even more.
In the 10 - 16 years age group most programs are general in that the athletes have similar programs unless individual problems or deficiencies are detected by coaches, physiotherapists or sport scientists. They do not yet specialize in racing disciplines, so it is important that the athletes develop an excellent general fitness base. Strength, power, strength endurance, coordination, and aerobic/anaerobic fitness (in no particular order) are part of age-appropriate general training programs. As a racing career progresses, most athletes specialize and do not ski all 4 alpine disciplines. Training will then become more specific as the athlete moves into the speed or technical disciplines. Downhillers tend focus less on power and quickness than slalom skiers, for example. Ski racing has become more 'athletic' in the last decade due to shorter skis with more side cut and binding plates. Quicker turns at higher speeds require skiers to be more agile and simply better athletes. There cannot be a 'cookie cutter' approach to producing top ski racers, as there is no prototype for success. Skiers have not only individual racing styles, but are unique physically as well.

**REFERENCES:**

Berg, H.E., Eiken, O. & Tesch, P.A. (1995). Involvement of eccentric muscle actions in giant slalom racing. Med Sci Sports Exerc, 27(12), 1666-1670.

Bosco, C. (1997). Evaluation and planning of conditioning training for alpine skiers. In: E. Müller, et al. (Eds.), Science and Skiing, (pp 229-250).

Brown, S.L. & Wilkinson, J.G. (1983). Characteristics of national, divisional and club male alpine ski racers. Med Sci Sports Exerc, 15(6), 491-495.

Frick, U., Schmidtbleicher, D., Raschner, C. & Müller, E. (1997). Types of muscle action of leg and hip extensor muscles in slalom. In: E. Müller, et al. (Eds.), Science and Skiing (pp 262-271).

Gröger, A., Oettl, G.M. & Tusker, F. (2001). Anthropometrische Daten und Kraftdiagnostik von Eishockey Junioren Nationalspielern. Sportverl Sportschad, 15, 87-91.

Hintermeister, R.A., O'Connor, D.D., Lange, G.W., Dillman, C.J. & Steadman J.R. (1997). Muscle activity in wedge, parallel and giant slalom skiing. Med Sci Sports Exerc, 29(4), 548-553.

Kellis, S.E., Tsitskaris, G.K., Nikopolou, M.D. & Mousikou, K.C. (1999). The evaluation of jumping ability of male and female basketball players according to their chronological age major leagues. J Strength and Con Res, 13(1), 40-46.

Kibler, W.B., Press, J. & Sciascia, A. (2006). The role of core stability in athletic function. Sports Med, 36(3), 189-198.

Kollath, E., Merheim, G., Braunleder, A. & Kleinöder, H. (2006). Sprintschnelligkeit und Sprungkraft von jugendlichen Leistungs- Fußballspielern. Leistungssport, 36(3), 25-28.

Leeturn, D.T., Ireland, M.L., Willson, J.D., Ballantyne, B.T. & Davis, I.M. (2004). Core stability measures as risk factors for lower extremity injury in athletes. Med Sci Sports Exerc, 36(6), 926-934.

Neumayr, G., Hoertnagl, H., Pfister R., Koller A., Eibl, G. & Raas, E. (2003). Physical and Physiological Factors Associated with Success in Professional Alpine Skiing. Int J Sports Medicine 24, 571-575.

Raschner, C., Huber, R., Staudacher, A., Kröll, J., Patterson C., Pühringer, R. & Müller E. (2004). Cornerstones of a holistic educational concept in youth alpine ski racing - exemplified by the Skigymnasium Stams. In: E. Müller, et al. (Eds.), Science and Skiing III (pp 148-165).

White, A.T. & Johnson, S.C. (1991). Physiological comparison of international, national and regional alpine skiers. Int J Sports Medicine 12(4), 374-378.